

WHAT IS CLAIMED IS:

- 1 1. A method of patterning an attenuated phase-shifting mask, comprising:
  - 2 providing a mask blank, wherein the mask blank has an attenuating and phase-shifting
  - 3 layer formed over a transparent layer, the phase-shifting layer having an initial thickness,
  - 4 wherein the initial thickness of the phase-shifting layer is adapted to provide a first
  - 5 predetermined phase shift for a first wavelength of light passing therethrough;
  - 6 reducing the initial thickness of the phase shifting layer to a first thickness; and
  - 7 removing portions of the phase-shifting layer to form a pattern of clear areas, wherein the
  - 8 first thickness of the phase-shifting layer at dark areas is adapted to provide a second
  - 9 predetermined phase shift for a second wavelength of light passing therethrough relative to the
  - 10 same light of the second wavelength passing through the clear areas, wherein the first
  - 11 wavelength differs from the second wavelength.
- 1 2. The method of claim 1, further comprising:
  - 2 removing portions of the transparent layer to form a recess with a first recess depth at the
  - 3 clear areas.
- 1 3. The method of claim 2, wherein the portions of the transparent layer are removed by  
2 reactive ion etching using an etch chemistry including at least one of SF<sub>6</sub> and CF<sub>4</sub>.
- 1 4. The method of claim 1, wherein part of the phase-shifting layer with a second thickness  
2 remains at the clear areas, wherein the second thickness is less than the first thickness.
- 1 5. The method of claim 1, wherein the second predetermined phase shift is approximately  
2 equal to or greater than the first predetermined phase shift.

- 1    6.       The method of claim 5, wherein the second wavelength is greater than the first
- 2       wavelength.
- 1    7.       The method of claim 1, wherein the first predetermined phase shift is about 180 degrees.
- 1    8.       The method of claim 1, wherein the second predetermined phase shift is equal to or
- 2       greater than about 180 degrees.
- 1    9.       The method of claim 1, wherein the initial thickness of the phase-shifting layer is adapted
- 2       to provide a first optical transmission for light of the first wavelength, and wherein the first
- 3       thickness of the phase-shifting layer at the dark areas is adapted to provide a second optical
- 4       transmission.
- 1    10.      The method of claim 9, wherein the second optical transmission is less than or equal to
- 2       about 6%.
- 1    11.      The method of claim 1, wherein the transparent layer comprises a quartz material.
- 1    12.      The method of claim 1, wherein the initial thickness of the attenuation and phase-shifting
- 2       layer is reduced by reactive ion etching using an etch chemistry including at least one of SF<sub>6</sub> and
- 3       CF<sub>4</sub>.

1    13.    A method of making a patterned attenuated phase-shifting mask from a mask blank, the  
2    mask blank including an attenuation and phase-shifting layer with a first default thickness and a  
3    transparent layer with a second default thickness, the attenuation and phase-shifting layer  
4    covering the transparent layer, the method comprising:

5               forming a circuit design pattern that includes forming a plurality of clear areas and  
6    forming a plurality of dark areas;

7               wherein the forming dark areas includes reducing a thickness of the attenuation and  
8    phase-shifting layer from the first default thickness to a first adjusted thickness; and

9               wherein forming clear areas includes:

10          removing portions of the attenuation and phase-shifting layer at clear areas, and  
11          reducing a thickness of the transparent layer at the clear areas from the second default  
12    thickness to a second adjusted thickness.

1    14.    The method of claim 13, wherein the transparent layer comprises a quartz material.

1    15.    The method of claim 13, wherein the attenuated phase-shifting mask is designed for light  
2    with a target wavelength, and wherein the first adjusted thickness and the second adjusted  
3    thickness are designed so that the phase of light passing through dark areas differs from the  
4    phase of light passing through clear areas by a predetermined phase shift.

1    16.    The method of claim 15, wherein the predetermined phase shift is about 180 degrees.

1    17.    The method of claim 13, wherein the attenuated phase-shifting mask is designed for light  
2    with a target wavelength, and wherein the first thickness is designed so that light passing through  
3    dark areas has a predetermined optical transmission.

1    18.    The method of claim 17, wherein the predetermined optical transmission is between  
2    about 5% and about 15%.

1    19.    The method of claim 17, wherein the predetermined optical transmission is between  
2    about 2% and about 20%.

1    20.    The method of claim 13, wherein the thickness of the attenuation and phase-shifting layer  
2    is reduced by etching.

1    21.    The method of claim 20, wherein the etching of the attenuation and phase-shifting layer  
2    includes reactive ion etching.

1    22.    The method of claim 21, wherein the reactive ion etching uses an etching chemical  
2    selected from a group consisting of SF<sub>6</sub> and CF<sub>4</sub>.

1    23.    The method of claim 13, wherein the portions of the attenuation and phase-shifting layer  
2    are removed by etching.

1    24.    The method of claim 23, wherein the etching of the attenuation and phase-shifting layer  
2    includes reactive ion etching.

1    25.    The method of claim 24, wherein the reactive ion etching uses an etching chemical  
2    selected from a group consisting of SF<sub>6</sub> and CF<sub>4</sub>.

1    26.    The method of claim 13, wherein the thickness of the transparent layer is reduced at the  
2    clear areas by etching.

1    27.    The method of claim 26, wherein the etching of the transparent layer includes reactive  
2    ion etching.

1    28.    The method of claim 27, wherein the reactive ion etching uses an etching chemical  
2    selected from a group consisting of SF<sub>6</sub> and CF<sub>4</sub>.

- 1    29. An attenuated phase-shifting mask comprising:
  - 2        a transparent layer;
  - 3        an attenuating and phase-shifting layer over the transparent layer;
  - 4        dark areas having the phase-shifting layer at a first thickness; and
  - 5        clear areas having the phase-shifting layer removed therefrom and having a recess of a
  - 6        recess depth formed in the transparent layer, wherein the first thickness at the dark areas and the
  - 7        first recess depth at the clear areas are chosen such that a certain phase-shift and transmittance is
  - 8        provided for light through the dark areas relative to the clear areas.
- 1    30. The attenuated phase-shifting mask of claim 29, wherein the transparent layer comprises  
2        quartz.
- 1    31. The attenuated phase-shifting mask of claim 29, wherein the attenuated phase-shifting  
2        mask is made from an attenuated phase-shifting mask blank having an attenuation and phase-  
3        shifting layer with an initial thickness greater than the first thickness at the dark areas.
- 1    32. The attenuated phase-shifting mask of claim 31, wherein the mask blank is designed for  
2        light with a first wavelength, but the attenuated phase-shifting mask formed therefrom is  
3        designed for light with a second wavelength, wherein the second wavelength differs from the  
4        first wavelength.
- 1    33. The attenuated phase-shifting mask of claim 32, wherein the second wavelength is  
2        smaller than the first wavelength.

- 1    34.    The attenuated phase-shifting mask of claim 29, wherein the certain phase-shift is equal
- 2    to or greater than about 180 degrees, and wherein the certain transmittance is less than or equal
- 3    to about 6%.

- 1    35. An attenuated phase-shifting mask comprising:
  - 2            a transparent layer;
  - 3            an attenuating and phase-shifting layer over the transparent layer;
  - 4            dark areas having the phase-shifting layer at a first thickness; and
  - 5            clear areas having the phase-shifting layer at a second thickness, wherein the first
  - 6            thickness at the dark areas is greater than the second thickness at the clear areas, and wherein the
  - 7            first thickness and second thickness are chosen such that a certain phase-shift and transmittance
  - 8            is provided for light through the dark areas relative to the clear areas.
- 1    36. The attenuated phase-shifting mask of claim 35, wherein the attenuated phase-shifting
- 2            mask is made from an attenuated phase-shifting mask blank having an attenuating and phase-
- 3            shifting layer with an initial thickness greater than the first thickness at the dark areas.
- 1    37. The attenuated phase-shifting mask of claim 36, wherein the mask blank is designed for
- 2            light with a first wavelength, but the attenuated phase-shifting mask formed therefrom is
- 3            designed for light with a second wavelength, wherein the second wavelength differs from the
- 4            first wavelength.
- 1    38. The attenuated phase-shifting mask of claim 37, wherein the second wavelength is
- 2            smaller than the first wavelength.
- 1    39. The attenuated phase-shifting mask of claim 35, wherein the certain phase-shift is equal
- 2            to or greater than about 180 degrees, and wherein the certain transmittance is less than or equal
- 3            to about 6%.